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32 YEARS OF CHANGES IN PASSERINE NUMBERS DURING SPRING AND FALL MIGRATIONS IN COASTAL MASSACHUSETTS

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ABSTRACT.—Using standardized mist-net captures collected over a 32-year period (1970–2001), we examined changes in the capture rates of passerines recorded in coastal Massachusetts during fall (78 species) and spring (72 species) migration. Capture rates of 45 species of fall migrants (58%) declined significantly between early (1970–1985) and late (1986–2001) years of the study; 36 species of spring migrants (50%) showed significant declines. Only Carolina Wren (*Thryothorus ludovicianus*), Tufted Titmouse (*Baeolophus bicolor*), Northern Cardinal (*Cardinalis cardinalis*), and Orchard Oriole (*Icterus spurius*) showed significant increases during spring migration; fall sampling indicated that Carolina Wren, Tufted Titmouse, Black-throated Blue Warbler (*Dendroica caerulescens*), and Northern Cardinal had significantly higher capture rates. Of 37 species included in the migration monitoring data but not reliably represented by Breeding Bird Survey (BBS) data in any of the northeastern physiographic strata, 23 (62%) showed significant declines at Manomet during at least one of the two migration periods. There were significant correlations in percent changes in migrant capture rates between fall and spring. BBS trends reported from the southern New England and northern New England physiographic strata were correlated with changes in migrant capture rates. However, there were also inconsistencies between results obtained by the two monitoring approaches, suggesting that factors in addition to actual changes in breeding populations may be reflected in the migration capture data. *Received 8 July 2003, accepted 26 March 2004.*

Monitoring passerine population changes through counts collected along migratory routes has been attempted often (Hussell 1981, Gauthreaux 1992, Hagan et al. 1992, Hussell et al. 1992, Peach et al. 1998, Ballard et al. 2003) despite a variety of issues that sometimes make the results of such studies difficult to interpret. In particular, detecting true changes in breeding populations may be confounded by weather effects that produce dramatic differences among years in the numbers of a particular species that appears during migration at a specific site (Gauthreaux 1971, Moore and Simons 1992, Dunn and Hussell 1995); while "fallouts" may provide exciting birding conditions, they also underscore the substantial stochastic element associated with any migration monitoring scheme. Habitat changes at a migration site also may cause apparent shifts in species' abundances that are unrelated to true population levels (Remsen and Good 1996). Furthermore, the specific breeding populations actually represented by samples of migrants are almost always unknown (Dunn and Hussell 1995), and conceivably may vary from year-to-year at a particular migration site under the influence of differing weather conditions. Thus, there is lit-

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tle doubt, as some have pointed out (Butcher et al. 1993, Sauer 1993, Remsen and Good 1996), that monitoring changes in breeding populations through counts of migrants obtained by mist-net captures is risky business.

Still, most long-term field observers will quickly counter that *something* is happening to the numbers of migrating land birds in eastern North America (Robbins et al. 1989, Terborgh 1989, Askins et al. 1990), and that these perceived changes are not easily discounted simply by the effects of weather variations or local habitat change. In fact, although short-term fluctuations in numbers of migrants recorded at a site may be completely meaningless, we contend that studies of longer duration—despite their inherent complications—may yet help to elucidate true population changes simply by virtue of their long-term perspective.

In this paper we present results, to date, of one of North America's longest migration monitoring efforts, conducted at Manomet Center for Conservation Sciences (formerly Manomet Bird Observatory, MBO) from the late 1960s to the present. A preliminary analysis of some of these data was presented by Hagan et al. (1992); herein, we extend the scope of this earlier work in terms of years, seasons, and species included. For 78 species in fall and 72 species in spring we examine, for the 32-year period 1970–2001, (a) changes in the numbers of individuals captured at Manomet's banding station in coastal Massachusetts, and (b) similarities in patterns of annual fluctuations of capture rates among species. We also compare changes in capture rates with estimates of population trends obtained through a very different type of monitoring study, the North American Breeding Bird Survey (BBS), which also has operated over this extensive time period (Robbins et al. 1986, Sauer 1993, Sauer et al. 2001).

METHODS

Manomet Center for Conservation Sciences, located on the western side of Cape Cod Bay, Plymouth County, Massachusetts (41° 50′ N, 70° 30′ W), is characterized by brushy, second-growth deciduous woodland, bordered on the east and south by a steep, eroding coastal bluff and on the west and north by brushy wetlands. Dominant tree species on the 7-ha plot include black cherry (*Prunus serotina*), shadbush (*Amelanchier* sp.), red maple (*Acer rubrum*), white oak (*Quercus alba*), and pitch pine (*Pinus rigida*). Common catbrier (*Smilax rotundifolia*), bayberry (*Myrica pensylvanica*), staghorn sumac (*Rhus typhina*), honeysuckle (*Lonicera morrowi*), arrowwood (*Viburnum recognitum*), and poison ivy (*Toxicodendron radicans*) are principal understory species.

Habitat succession was, for the most part, unchecked during the study period, but the site's location on an exposed coastal bluff resulted in annual natural "pruning" by harsh winter storms that probably reduced the degree of change in habitat structure over time. Small fields and grassland borders within the study site are mowed routinely. Historic photos of the area indicate that during the early 1920s most of the study area consisted of open sheep pastures, but by the time banding operations were begun in 1966 the site had already acquired the brushy, second-growth condition that characterizes it today. An individual black cherry tree was photographed in 1966, with a bander for height comparison, in a net lane about 10 m inland from the ocean bluff. By 2003, the tree had grown an estimated 25% in height, probably typical for the exposed coastal net lanes.

From 45 to 50 nylon mist nets (12 m long, 2.6 m high, 4 panels, 36 mm extended mesh) were operated annually from 1970 to 2001, inclusive; because of less complete coverage and imprecise records regarding capture effort expended during the first 4 years of the observatory's existence (1966–1969), we excluded these years from analysis. Nets were kept at fixed locations throughout the study. Opening and closing times of nets were recorded and used for calculating daily capture effort (Robbins 1968); except for closures during adverse weather conditions, generally nets were operated from 0.5 hr prior to sunrise to 0.5 hr after sunset. Thus, 50 nets open for 12 hr equals 600 net hr. Sampling was conducted 5–7 days per week during spring (15 April–15 June) and fall (15 August–15 November) migration.

During the study period, 205,454 individuals of 159 species were banded. Records used in this analysis were selected from the overall database using criteria described be-low. Only passerines are considered here; scientific names and abbreviation codes for species referenced in the text are provided in the Appendix. Willow and Alder flycatchers were combined, as were Bicknell's and Gray-cheeked thrushes. Palm Warbler races were treated separately as "Yellow" and "Western" Palm warblers. Captures of hybrid "Brewster's" ($n = 3$) and "Lawrence's" ($n = 2$) warblers were counted as Blue-winged Warblers. Repeat captures were eliminated. Locally breeding birds, identified on the basis of well-developed brood patches or cloacal protuberances, were eliminated, as were spring captures of hatching-year (HY) individuals. Species that were captured, by season, in fewer than 15 of the 32 years, were eliminated.

For each species, by season, migration windows were calculated as falling between the 1st and 99th percentiles of all capture dates across all years; any records outside these windows were excluded. These cutoff values are provided in the Appendix. For example, during fall migration, 98% of all captures of American Redstarts occurred from 17 August to 12 October. Any banding activity that took place within this window was considered to represent a legitimate sampling day for this species; days that yielded no redstart captures, but on which nets were open, contributed a value of zero to the overall calculation of capture rate. Any redstart captures that occurred before 17 August or after 12 October were excluded.

For each species (by year and season), we calculated a mean capture rate weighted by the number of hours of mist netting that occurred on each contributing date. That is, in calculating mean seasonal and annual capture rates for a species, the rate obtained on a day when nets were open for 400 net hr was given more emphasis than a rate obtained on a day when only 10 net hr of sampling took place. We used Wilcoxon 2-sample tests to examine long-term trends by testing (for each species, by season) the hypothesis that mean capture rates were equal between Early (1970–1985) and Late (1986–2001) years of the study.

Spearman rank correlations were used to assess concordance between each species' fall and spring capture rates, and between the percent change in mean capture rates (Early versus Late) for each species and the population trends provided by BBS data (Sauer et al. 2001). These authors commendably cautioned that "Small sample sizes, low relative abundance on survey routes, imprecise trends, and missing data all can compromise BBS results. Often, users do not take these problems into account when viewing BBS results, and use the results inappropriately." When we refer to BBS trends in this paper, we conservatively include only instances where the BBS "Regional Credibility Measure" was in the best-sampled, "blue" category. That is, BBS trends considered by Sauer et al. (2001) to include "important deficiencies" (red) and "deficiencies" (yellow) were not used in the correlation analyses.

Presentation of graphs showing changes in capture rates for each species and season combination in this study would require 150 individual figures. Although obviously beyond the space limitations of this publication, these results are provided online at www.manomet.org. Here, in order to visually summarize major patterns of variation within this large set of data, we calculated 3-year moving averages based on annual mean capture rates, then standardized each of these values as a percent of the maximum rate encountered for each species among all years (by season). Next, we used Ward's minimum variance clustering approach, as implemented by JMP statistical software (SAS Institute, Inc. 2001), to identify, for each season, an arbitrary six groups of species that exhibited similar year-to-year fluctuations in capture rates. Finally, we plotted means and standard errors, calculated from the moving averages for species belonging to each of these clusters.

RESULTS

Of 72 species captured during spring migration, 60 (83%) had lower mean capture rates during 1986–2001 than during 1970–1985 (Table 1). These declines were significant ($P < 0.05$) in 36 species. Twelve species showed higher capture rates during 1986–2001 than during 1970–1985; in four of these (Carolina Wren, Tufted Titmouse, Northern Cardinal, and Orchard Oriole), the increases from Early to Late sampling periods were significant ($P < 0.01$).

During fall migration, 69 of 78 species

TABLE 1. Mean capture rates and percent change between Early (1970–1985) and Late (1986–2001) sampling periods during spring and fall migrations. Population trend data from Breeding Bird Survey (BBS) presented for comparison.

	Spring capture rate[a]			Fall capture rate[a]			BBS[b]		
Species	Early	Late	(% change)	Early	Late	(% change)	SH	nNE	sNE
Eastern Wood-Pewee	0.766	0.464	(−39)	0.183	0.141	(−23)	D	D	d
Yellow-bellied Flycatcher	1.539	1.336	(−13)	0.455	0.297	(−35)*	[i]	I	
Acadian Flycatcher	0.234	0.206	(−12)						[d]
Willow/Alder Flycatcher	3.269	3.730	(14)	0.754	0.557	(−26)	[i]	I	[I]
Least Flycatcher	0.844	0.674	(−20)	0.866	0.328	(−62)**	D	D	D
Eastern Phoebe	0.210	0.200	(−5)	0.531	0.574	(8)	[I]	[i]	[i]
Great Crested Flycatcher	0.535	0.813	(52)				D	I	D
Eastern Kingbird	0.342	0.280	(−18)	0.477	0.108	(−77)*	D	d	D
White-eyed Vireo	0.360	0.155	(−57)**	0.143	0.092	(−36)			[I]
Blue-headed Vireo	0.313	0.265	(−15)	0.461	0.610	(32)	I	I	[i]
Warbling Vireo				0.131	0.074	(−44)	[i]	I	i
Philadelphia Vireo				0.379	0.208	(−45)**	[i]	[i]	
Red-eyed Vireo	1.316	0.783	(−40)*	4.317	2.834	(−34)*	I	[d]	[d]
Blue Jay	7.071	2.767	(−61)**	2.326	1.289	(−45)*	[i]	i	D
Black-capped Chickadee	3.176	0.773	(−76)	37.479	18.411	(−51)	I	I	i
Tufted Titmouse	0.162	0.593	(266)**	3.672	6.520	(78)*	[i]	[I]	[I]
Red-breasted Nuthatch				0.291	0.092	(−68)	I	I	[i]
White-breasted Nuthatch				0.156	0.204	(31)	[i]	I	i
Brown Creeper	0.471	0.148	(−69)**	2.750	1.320	(−52)***	[i]	[i]	[d]
Carolina Wren	0.043	0.146	(240)***	0.072	0.546	(658)***			[I]
House Wren	0.368	0.166	(−55)*	0.269	0.182	(−32)	[d]	[D]	[D]
Winter Wren				0.325	0.224	(−31)	[I]	[i]	[i]
Golden-crowned Kinglet	0.454	0.943	(108)	5.176	3.981	(−23)	I	[i]	
Ruby-crowned Kinglet	4.793	3.014	(−37)	2.964	1.917	(−35)	D	[i]	
Blue-gray Gnatcatcher	0.724	0.385	(−47)**	0.344	0.255	(−26)		[I]	[I]
Veery	1.617	0.722	(−55)**	0.909	0.534	(−41)*	[D]	D	d
Gray-cheeked/Bicknell's Thrush	0.415	0.140	(−66)**	0.342	0.190	(−44)**			
Swainson's Thrush	4.708	2.069	(−56)**	2.181	0.996	(−54)**	[D]	[d]	
Hermit Thrush	3.545	3.706	(5)	3.022	2.548	(−16)	[I]	[i]	[d]
Wood Thrush	1.211	0.398	(−67)***	0.306	0.113	(−63)***	D	[D]	D
American Robin	0.767	0.420	(−45)**	7.925	3.382	(−57)**	i	[d]	d
Gray Catbird	32.243	23.340	(−28)**	24.028	17.410	(−28)**	[D]	D	I
Northern Mockingbird	0.176	0.203	(15)	0.671	0.327	(−51)*	[I]	[I]	[I]
Brown Thrasher	0.893	0.364	(−59)***	0.400	0.111	(−72)***	[D]	[D]	D
Cedar Waxwing	0.499	0.882	(77)	0.474	0.314	(−34)	i	I	I
Blue-winged Warbler				0.228	0.234	(3)		[d]	D
Tennessee Warbler	0.938	0.048	(−95)***	0.381	0.069	(−82)***	[i]	[d]	
Orange-crowned Warbler				0.244	0.157	(−36)	[d]		

TABLE 1. Continued.

Species	Spring capture rate[a]			Fall capture rate[a]			BBS[b]		
	Early	Late	(% change)	Early	Late	(% change)	SH	nNE	sNE
Nashville Warbler	0.304	0.122	(−60)*	0.666	0.428	(−36)*	i	[d]	[d]
Northern Parula	0.555	0.287	(−48)**	0.116	0.050	(−57)*	[I]	[i]	[i]
Yellow Warbler	1.574	1.162	(−26)*	0.528	0.168	(−68)**	[i]	d	[I]
Chestnut-sided Warbler	0.292	0.171	(−41)	0.162	0.126	(−22)	d	[D]	d
Magnolia Warbler	5.105	5.572	(9)	0.998	0.881	(−12)	I	d	[i]
Cape May Warbler				1.087	0.077	(−93)***	[i]	[i]	
Black-throated Blue Warbler	0.910	0.861	(−5)	0.549	0.781	(42)*	[i]	i	[i]
Yellow-rumped (Myrtle) Warbler	1.285	0.965	(−25)	45.991	17.639	(−62)***	I	I	[I]
Black-throated Green Warbler	0.208	0.098	(−53)*	0.325	0.250	(−23)	[nc]	i	[I]
Blackburnian Warbler	0.155	0.090	(−42)*	0.093	0.028	(−70)**	i	[d]	[d]
Prairie Warbler	0.318	0.235	(−26)	0.249	0.187	(−25)		[i]	[D]
Palm Warbler (western)				0.543	0.132	(−76)***			
Palm Warbler (yellow)	0.706	0.900	(28)				[I]		
Bay-breasted Warbler	0.338	0.121	(−64)	1.822	0.254	(−86)***	[D]	[i]	
Blackpoll Warbler	2.881	1.384	(−52)**	14.753	4.268	(−71)***	[d]	[i]	
Black-and-White Warbler	5.244	3.310	(−37)**	1.643	0.802	(−51)**	i	d	d
American Redstart	7.394	4.777	(−35)**	6.351	2.889	(−55)***	d	d	[I]
Ovenbird	2.991	2.057	(−31)*	0.726	0.586	(−19)	[nc]	I	nc
Northern Waterthrush	3.424	2.091	(−39)	1.341	0.654	(−51)***	[d]	[nc]	[nc]
Connecticut Warbler				0.232	0.151	(−35)	[d]		
Mourning Warbler	1.688	1.531	(−9)	0.447	0.244	(−45)**	[d]	[d]	
Common Yellowthroat	9.441	6.769	(−28)*	2.294	1.287	(−44)***	d	D	D
Wilson's Warbler	2.733	1.310	(−52)**	1.150	0.735	(−36)**	[i]		
Canada Warbler	4.548	2.378	(−48)**	0.925	0.596	(−36)*	d	d	[d]
Yellow-breasted Chat				1.334	0.645	(−52)***			[D]
Scarlet Tanager				0.418	0.108	(−74)***	[d]	D	[d]
Eastern Towhee	3.453	1.148	(−67)***	1.135	0.264	(−77)***	[D]	D	D
American Tree Sparrow				0.448	0.140	(−69)**			
Chipping Sparrow	0.165	0.076	(−54)				[d]	[I]	[I]
Field Sparrow	0.144	0.030	(−79)**	0.478	0.104	(−78)***	[d]	D	D
Savannah Sparrow	0.314	0.096	(−70)**				[D]	[i]	[D]
Fox Sparrow				0.181	0.073	(−60)*	[d]		
Song Sparrow	1.174	0.589	(−50)*	2.829	1.952	(−31)*	[D]	[D]	D
Lincoln's Sparrow	0.744	0.418	(−44)	0.314	0.208	(−34)	[i]		
Swamp Sparrow	2.624	1.349	(−49)	1.476	1.447	(−2)	i	i	[i]
White-throated Sparrow	17.076	14.091	(−17)	13.389	7.580	(−43)**	D	D	[D]
White-crowned Sparrow	0.194	0.098	(−50)	0.337	0.145	(−57)*			
Dark-eyed (Slate-colored) Junco	0.915	0.379	(−59)**	4.126	1.474	(−64)***	D	d	[d]

TABLE 1. Continued.

Species	Spring capture rate[a]			Fall capture rate[a]			BBS[b]		
	Early	Late	(% change)	Early	Late	(% change)	SH	nNE	sNE
Northern Cardinal	0.285	0.764	(168)***	0.615	1.444	(135)***	[I]	I	[I]
Rose-breasted Grosbeak	0.199	0.046	(−77)*	0.101	0.034	(−66)**	[D]	[i]	[D]
Indigo Bunting	0.125	0.048	(−61)*	0.076	0.056	(−26)	i	d	D
Red-winged Blackbird	1.219	0.641	(−47)**				[D]	[d]	D
Common Grackle	1.412	1.044	(−26)				d	D	D
Brown-headed Cowbird	0.634	0.259	(−59)**				[D]	D	d
Orchard Oriole	0.170	0.502	(194)**						[d]
Baltimore Oriole	2.671	1.247	(−53)**	1.100	0.676	(−39)*	[D]	[i]	[D]
Purple Finch				1.213	0.168	(−86)***	D	D	[D]
House Finch	0.136	0.116	(−15)	0.375	0.249	(−34)	[I]	[I]	[I]
American Goldfinch	1.175	0.953	(−19)	0.233	0.390	(67)	[d]	[i]	[i]

[a] Based on weighted means of capture rates, by year and season (n = 16 in both Early and Late periods). % Change = (Late − Early)/Early × 100. Significant differences between mean Early and Late capture rates (Wilcoxon 2-sample test) indicated by asterisks: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

[b] Based on Sauer et al. (2001) analysis of 1966–2000 BBS data from physiographic strata 28 (SH, eastern Spruce-Hardwoods), 27 (nNE, northern New England), and 12 (sNE, southern New England). D = significant ($P < 0.05$) decline; d = non-significant ($P \geq 0.05$) decline; I = significant increase; i = non-significant increase; nc = no change. Symbols in brackets [ ] indicate that Sauer et al. (2001) considered these trend estimates unreliable due to "deficiencies" or "important deficiencies" in sampling. Blanks indicate physiographic regions where a given species was not represented in BBS trend data.

(88%) had lower capture rates during Late years of the study than during Early years (Table 1); these differences were significant ($P < 0.05$) in 45 species. Nine species had higher capture rates during 1986–2001 than during 1970–1985; in four of these (Carolina Wren, Tufted Titmouse, Black-throated Blue Warbler, and Northern Cardinal), the differences were significant ($P < 0.05$).

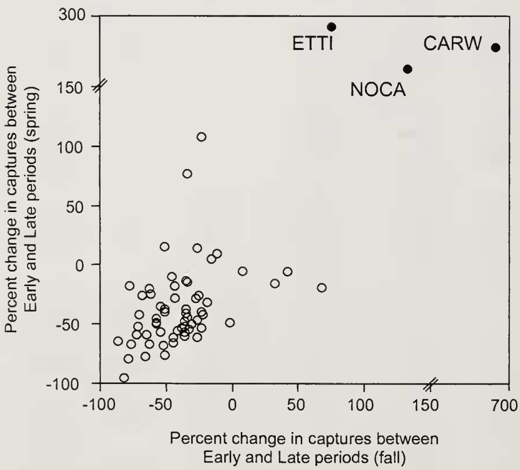

FIG. 1. Correlations between spring and fall migration periods for percent change in capture rates between Early and Late periods of the study ($P < 0.001$, n = 63 species). Three apparent outliers (CARW, Carolina Wren; ETTI, Tufted Titmouse; and NOCA, Northern Cardinal) shown as solid circles.

Percent changes in mean capture rates from Early to Late years of the study were positively correlated between spring and fall migrations (Rho = 0.55, $P < 0.001$, n = 63 species; Fig. 1). Exclusion of three outliers (Carolina Wren, Tufted Titmouse, and Northern Cardinal) that showed dramatic increases in capture rates during both migration periods did not substantially alter the strength of the observed correlation (Rho = 0.48, $P < 0.001$, n = 60 species). There were no species that showed significant increases in capture rate during one season and significant decreases in the other.

Because of uncertainty regarding the location of breeding populations represented by migrants in coastal Massachusetts, we compared our results with BBS trends from three physiographic regions (southern New England, northern New England, and eastern Spruce–Hardwoods) that we considered the most likely sources of the majority of migrants observed at Manomet (Fig. 2). Captures of spring migrants were significantly ($P <$

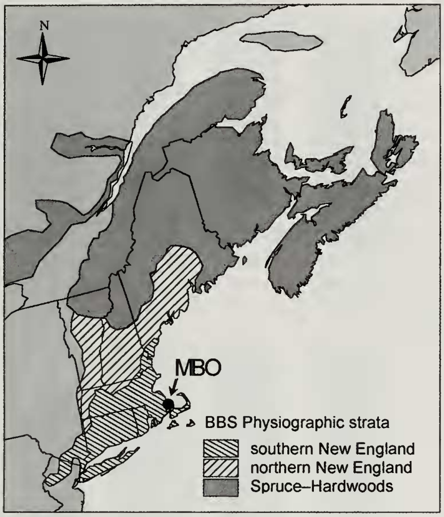

FIG. 2. Location of Manomet Center for Conservation Sciences (MBO) study site relative to three northeastern physiographic strata used in analysis of Breeding Bird Survey data.

0.05) and positively correlated with BBS trends from northern New England; during fall migration, we found significant positive correlations between capture rates and BBS trends from both southern and northern New England physiographic strata (Table 2).

Four species that breed at high latitudes or high elevations [Gray-cheeked/Bicknell's Thrush, Palm Warbler (western), American Tree Sparrow, and White-crowned Sparrow] were represented in the migration monitoring data but not by BBS analyses; all of these species showed significantly declining capture rates ($P < 0.05$) between Early and Late periods of the study. Thirty-three species represented in the migration monitoring data were considered by Sauer et al. (2001) to be represented unreliably by BBS data in any of the northeastern physiographic strata (Table 1); 19 of these species (Philadelphia Vireo, Brown Creeper, House Wren, Blue-gray Gnatcatcher, Swainson's Thrush, Northern Mockingbird, Tennessee Warbler, Northern Parula, Cape May Warbler, Bay-breasted Warbler, Blackpoll Warbler, Northern Waterthrush, Mourning Warbler, Wilson's Warbler, Yellow-breasted Chat, Savannah Sparrow, Fox Sparrow, Rose-breasted Grosbeak, and Baltimore Oriole) showed significant declines at Manomet during at least one of the two migration periods,

TABLE 2. Correlations between percent change in mean capture rates (Early versus Late sampling periods) and Breeding Bird Survey trends (Sauer et al. 2001) from three physiographic regions. BBS results with "deficiencies" or "important deficiencies" have been excluded from analysis (see text).

	Physiographic region[a]		
	sNE	nNE	SH
Spring	0.36 (0.087)[b]	0.45 (0.011)	0.17 (0.402)
	$n = 23$	$n = 31$	$n = 26$
Fall	0.50 (0.018)	0.47 (0.006)	0.34 (0.087)
	$n = 22$	$n = 33$	$n = 26$

[a] sNE = southern New England, nNE = northern New England, SH = eastern Spruce-Hardwoods.
[b] Spearman rank correlation (P-value).

while capture rates of 3 (Tufted Titmouse, Carolina Wren, and Orchard Oriole) significantly increased during fall and spring migrations (Table 1).

Apparent inconsistencies between trends based on migration captures at Manomet and BBS data were greatest for the eastern Spruce–Hardwoods stratum and least for the southern New England stratum. This pattern was true during both spring (Fig. 3) and fall (Fig. 4) migration periods. Spring migration captures indicated significant ($P < 0.05$) declines in three species for which BBS analyses found significant increases: Red-eyed Vireo (eastern Spruce–Hardwoods), Ovenbird (northern New England), and Gray Catbird (southern New England). Fall migration captures significantly declined in four species whereas BBS analyses showed significant increases: Red-eyed Vireo and Yellow-rumped (Myrtle) Warbler (eastern Spruce–Hardwoods), Yellow-bellied Flycatcher and Yellow-rumped (Myrtle) Warbler (northern New England), and Gray Catbird (southern New England).

For each migration period, cluster analysis was used to identify an arbitrary six groups of species that shared general patterns of change in capture rates across years (Figs. 5 and 6). This approach allowed us to summarize trend data visually for a large number of species. However, we note that similarities in capture rates among members of a group do not necessarily mean that shared trends were caused by similar proximate factors. In some cases cluster membership may, in fact, reflect the influence of shared ecology. For example,

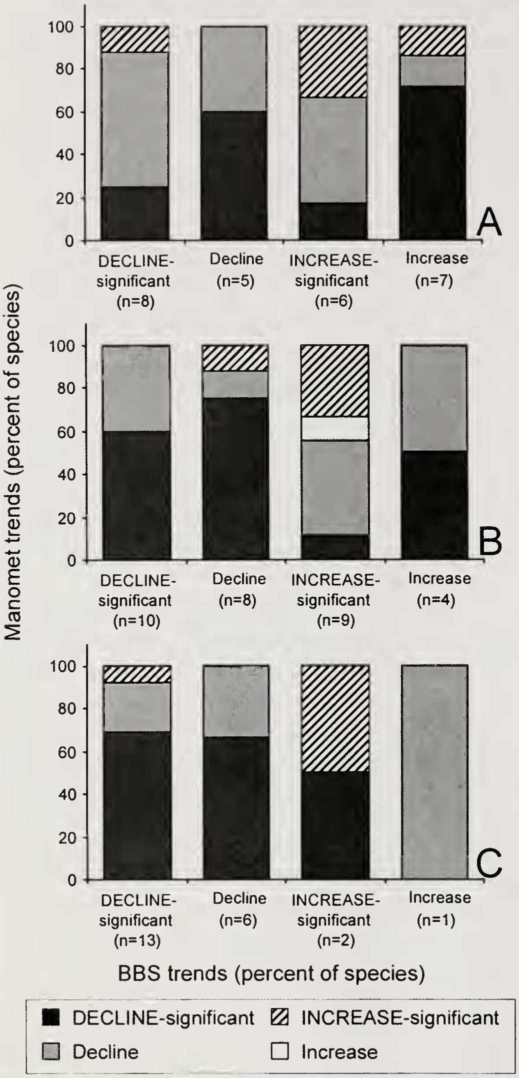

FIG. 3. Comparison of trends in capture rate based on spring migration monitoring at Manomet relative to trends derived from BBS data (Sauer et al. 2001) in (A) spruce-hardwoods, (B) northern New England, and (C) southern New England physiographic strata. "DECLINE-significant," $P < 0.05$; "Decline," $P \geq 0.05$; "INCREASE-significant," $P < 0.05$; "Increase," $P \geq 0.05$. For example, of 13 species showing significant declines according to BBS data from southern New England, 70% showed significant declines in Manomet capture rates, and 20% showed declines in Manomet capture rates that were not statistically significant.

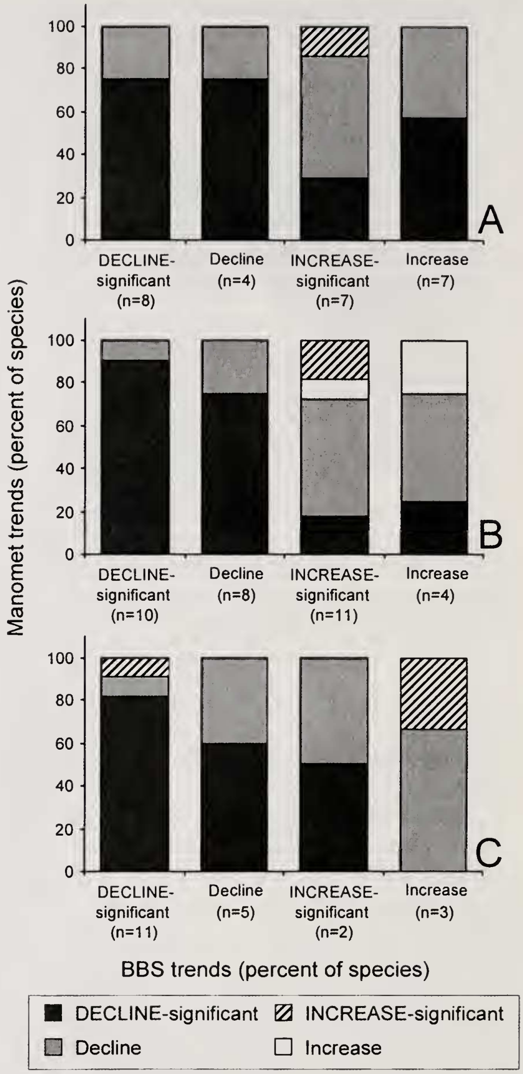

FIG. 4. Comparison of trends in capture rate based on fall migration monitoring at Manomet relative to trends derived from BBS data (Sauer et al. 2001) in (A) spruce-hardwoods, (B) northern New England, and (C) southern New England physiographic strata. "DECLINE-significant," $P < 0.05$; "Decline," $P \geq 0.05$; "INCREASE-significant," $P < 0.05$; "Increase," $P \geq 0.05$.

capture rates of Blackpoll Warbler, Northern Parula, Tennessee Warbler, Cape May Warbler, Blackburnian Warbler, and Bay-breasted Warbler peaked during the mid to late 1970s (Fig. 6F); many, if not all, of these species likely responded to a widespread outbreak of spruce budworm (*Choristoneura fumerifana* Clem.) in eastern North America during this time period (Hagan et al. 1992). Carolina Wren and Northern Cardinal, two species known to have shown dramatic regional population increases during the last decades (Ha-

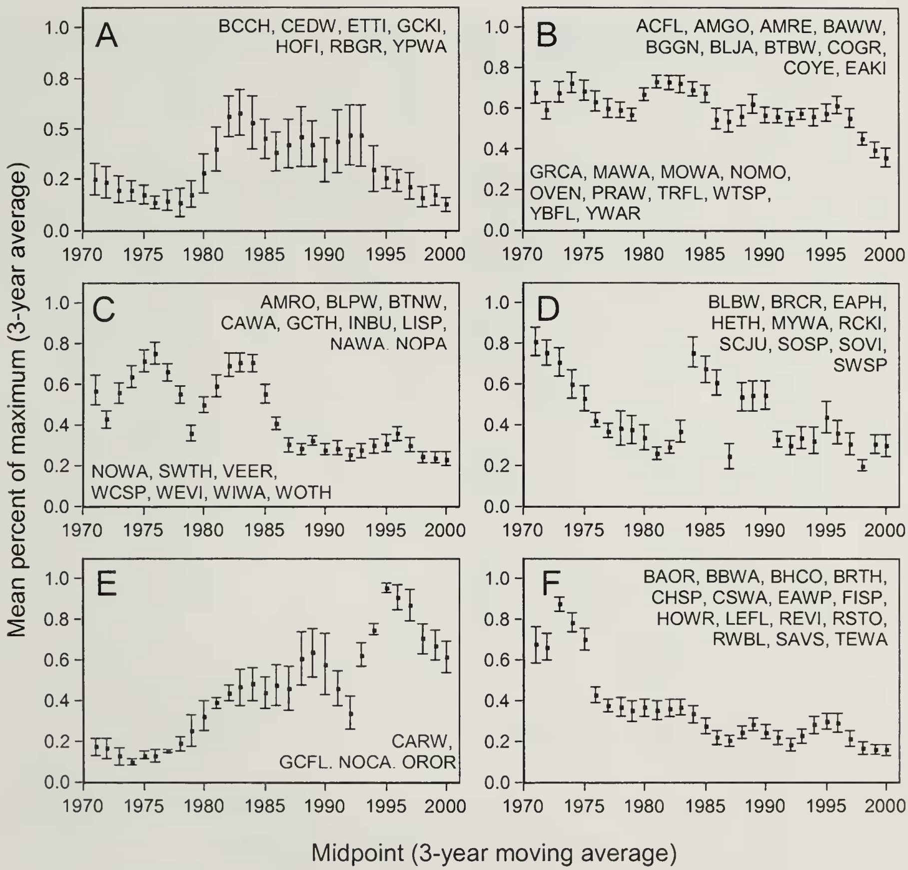

FIG. 5. Major patterns of change in spring capture rates of 72 species in coastal Massachusetts, 1970–2001. Error bars represent ± 1 SE. Species contributing to each plot are indicated with four-letter banding codes; see Appendix.

gan et al. 1992), were grouped together during both spring (Fig. 5E) and fall (Fig. 6C) migrations.

We speculate that at least some of the clustering results (and, therefore, underlying trend patterns) may reflect local weather conditions that would have influenced capture rates of species with similar migration periods. There were significant differences among mean migration dates for each of the six clusters (Fig. 7; Wilcoxon rank sum test; spring: $\chi^2 = 19.34$, df = 5, $P = 0.002$; fall: $\chi^2 = 16.12$, df = 5, $P = 0.007$). During spring, most species assigned to clusters A and D (Fig. 5A, D) were relatively early migrants, with mean migration dates of 7 May (SE = 4.5 days) and 3 May (SE = 3.4 days), respectively; both of these groups showed somewhat elevated capture rates during the mid to late 1980s, possibly suggesting that during several years in this time period weather conditions caused larger-than-normal numbers of these species to be present in coastal Massachusetts. Similarly, most species assigned to fall cluster A (Fig. 6A) were relatively late migrants, with a mean migration date of 9 October (SE = 3.3 days); the relatively high capture rates that characterized this group during the early 1970s may have reflected local weather conditions that affected any species with a peak migration period in early October.

Nonetheless, we hesitate to try and provide further explanations for the species "memberships" in each of these groupings. Instead, we prefer to emphasize a more general perspective, noting that only one of the six trend plots from each migration period (spring: Fig. 5E; fall: Fig. 6C) showed obvious increases in

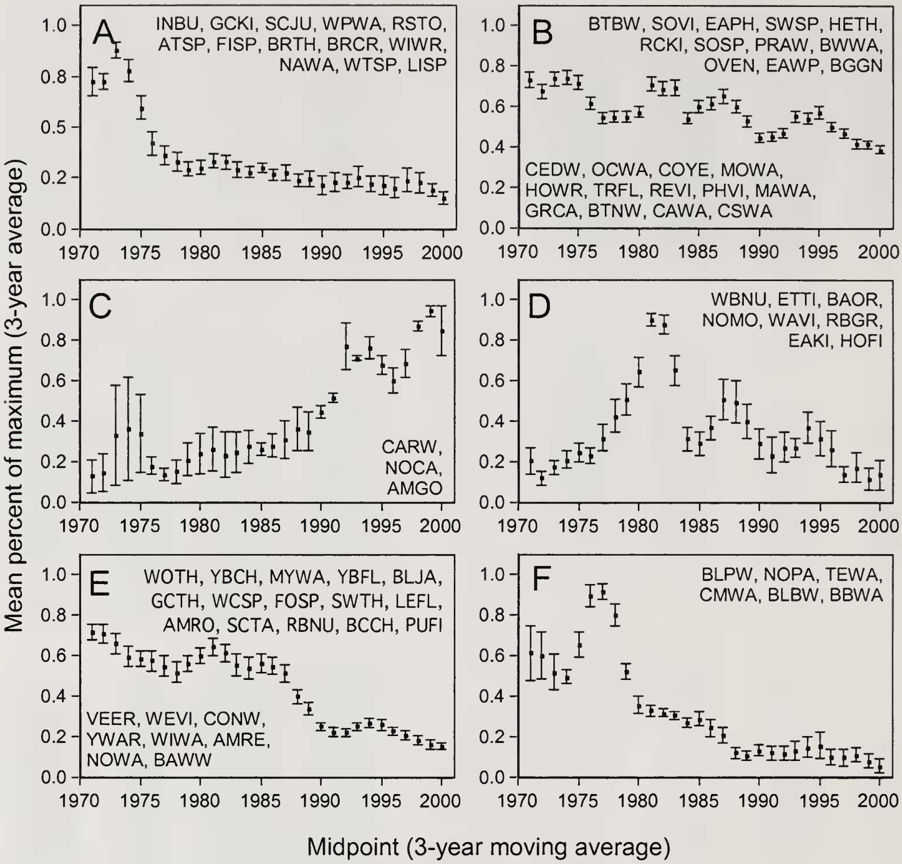

FIG. 6. Major patterns of change in fall capture rates of 78 species in coastal Massachusetts, 1970–2001. Error bars represent ± 1 SE. Species contributing to each plot are indicated with four-letter banding codes; see Appendix.

capture rates. Four of the plots from each migration period (spring: Fig. 5B–D, F; fall: Fig. 6A–B, E–F) showed decreasing trends in capture rates. One plot from each migration period was characterized by peak capture rates during the early to mid 1980s, with comparably low rates before and after this time period (spring: Fig. 5A; fall: Fig. 6D).

DISCUSSION

The Breeding Bird Survey is widely recognized as a primary source of information regarding conservation priorities for North American birds (Geissler and Noon 1981, Butcher et al. 1993, Smith et al. 1993, James et al. 1996, Carter et al. 2000), yet relatively few studies have attempted to validate its conclusions via independent, alternative monitoring schemes. Hussell et al. (1992) compared a migration index from 1961 to 1988 at Long Point, Ontario with BBS trends in that province and obtained positive correlations, as did Francis and Hussell (1998) in Ontario. Other multiple-year comparisons with BBS data have included intensive counts in Quebec (Jobin et al. 1996) and migration monitoring at Southeast Farallon Island, California (Pyle et al. 1994) and at Point Reyes, California (Ballard et al. 2003). In this paper we present results from a long-term study based on standardized mist-net capture efforts during fall and spring migrations in coastal Massachusetts, and compare these data with estimates of population trends obtained by Sauer et al. (2001) in their analysis of BBS data.

At first glance it would appear that there is good agreement between our results and BBS analyses. There were strong correlations be-

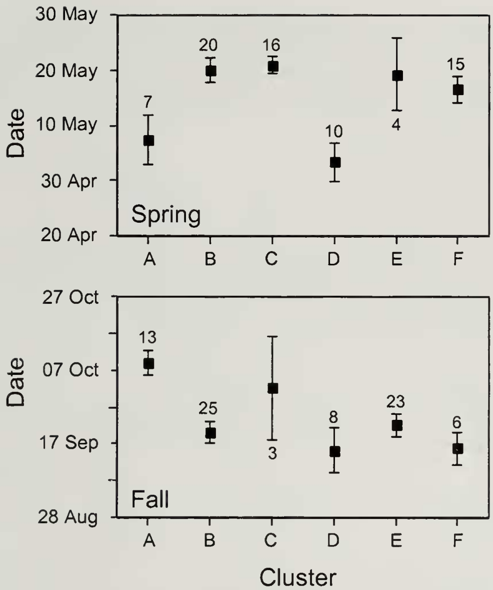

FIG. 7. Mean migration dates during spring and fall for clusters derived from capture trends. Cluster letters correspond with those shown in Fig. 5 (spring) and Fig. 6 (fall). Error bars represent ± 1 SE.

tween population trends observed in each of the three BBS strata considered here and changes in Manomet capture rates between 1970–1985 and 1986–2001, suggesting that both methods do, in fact, reflect changes in regional breeding populations. For example, Least Flycatcher was the only species to decline significantly in all three northeastern BBS strata, and it showed a significant decline in capture rate during fall at Manomet. Of 10 species for which significant declines were noted in two of three northeastern BBS strata, we found significant declines in capture rates during at least one of the two migration seasons for 7 (Eastern Kingbird, Wood Thrush, Common Yellowthroat, Eastern Towhee, Field Sparrow, White-throated Sparrow, and Purple Finch); 2 of the other species (Eastern Wood-Pewee and Common Grackle) declined non-significantly at Manomet, while Great Crested Flycatcher showed a non-significant increase based on migration data. Of 23 species for which the BBS showed significant population declines in at least one of the three physiographic strata considered here, 18 (78%) also showed significant declines in capture rates during spring and/or fall migration.

Yet the situation is more complex than these comparisons might suggest. In many cases our study failed to detect increasing population trends indicated by the BBS. Of 16 species shown by Sauer et al. (2001) to have had significant increases in at least one of the physiographic strata considered here, we found significantly increased capture rates in only 1 (Northern Cardinal). Furthermore, we observed significant declines in capture rates during spring and/or fall migration for five species found by the BBS to be exhibiting significant population increases in at least one of the three physiographic strata [Yellow-bellied Flycatcher, Red-eyed Vireo, Gray Catbird, Yellow-rumped (Myrtle) Warbler, and Ovenbird].

In our study we found significantly declining capture rates during one or both migration periods in 54 of 87 species (62%), but only 5 species (6%) showed significant increases. Among the 37 of these species for which reliable BBS results were available from at least one of the northeast's physiographic strata, Sauer et al. (2001) found significant declines in 22 cases (59%) and significant increases in 15 (41%); Great Crested Flycatcher and Gray Catbird showed opposite significant trends in different physiographic strata. These contrasts suggest that factors in addition to changes in breeding populations may be confounding the relationship with capture rates observed during migration.

We especially note that the patterns we describe here could have emerged if captures of most species we sampled during migration were somehow being reduced, over time, by factors unrelated to actual changes in breeding populations. For example, long-term changes in climate conceivably could cause shifts in regional weather patterns that, in turn, might systematically affect the number of migrants appearing in coastal Massachusetts (Moore et al. 1993). However, we are not aware of any evidence of long-term increases in migration captures at established banding operations east of the Mississippi that might be expected if actual migration patterns were changing. Or, as the vegetation at Manomet has matured since 1970, some species of migrants may now move through the study area at heights where they simply avoid making contact with the nets (2.6 m in height) (Remsen and Good 1996); species that would continue to be active primarily within 3 m of the ground, even in the presence of higher canopy cover, might be avoiding the site because of its generally more forested aspect (Moore et al. 1993).

Conversely, the BBS results may themselves be subject to error due to the effects of roadside bias (Temple and Wiens 1989, Keller and Fuller 1995) or short count period (Welsh 1995, Jobin et al. 1996); thus; the trend estimates by Sauer et al. (2001) may not necessarily provide a "gold standard" by which to validate Manomet's migration count results. It is also quite possible that a species could be increasing in one BBS stratum and decreasing in another, or showing conflicting trends within different regions of a single stratum—any of which could confuse the relationship between trends shown by the BBS and migration monitoring data sets. One of the three BBS strata considered here, the eastern Spruce-Hardwood forest, is so large (353,538 km^2; Rosenberg and Hodgman 2000) that presentation of a single trend to represent this entire area seems fraught with uncertainty at least equal to our lack of knowledge about the detailed breeding locations of migrants passing through Manomet.

At this point we have no way of further assessing these possible explanations. Certainly capture rates of migrants at Manomet during spring and fall have, in many cases, changed substantially from 1970 to 2001, and the vast majority of these changes have been declines. Migration count data from other studies also indicate long-term declines in New England birds; for example, Hill and Hagan (1991) found that spring surveys of 26 Neotropical migrants in Middlesex and Essex counties of Massachusetts declined, on average, nearly 1% per year from 1954 to 1987. Personal comments from several banders familiar with the location for 30+ years all indicate that there are fewer birds in recent years at Manomet and in New England generally.

Many of the declines documented at Manomet coincide with declines in breeding populations reported by the most reliable BBS data. Nonetheless, there are some apparent inconsistencies between results of the two analyses that we cannot explain. It appears likely that a combination of factors have influenced the number of migrants captured at Manomet since 1970. We believe, however, that the preponderance of data suggests long-term population declines in a wide variety of both Neotropical and shorter-distance migrants that greatly exceed the few increases that have been observed.

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It is impossible for us to name all of the contributors to this project, many of whom have given their time faithfully since the late 1960s. Hosts of students and volunteers have foregone sleep and decent salaries in order to spend their days walking net lanes. The trustees and friends of Manomet Center for Conservation Sciences made this work possible through unfailing personal and financial assistance. We deeply appreciate the support that all of you have given; from Cranberry Hill to Stage Point, your enthusiasm and dedication will always endure. Thank you. C. J. Ralph, C. S. Robbins, and an anonymous reviewer provided helpful comments on a preliminary draft of the manuscript. We dedicate this paper to K. Anderson and those initial banders whose vision and passion gave birth to Manomet Bird Observatory.

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APPENDIX. Banding codes, scientific names, and migration periods of species referred to in text. For each season, the limits of sampling window (1st and 99th percentiles) are given in parentheses following the mean date of migration (all years combined). Dashes (—) indicate species-season combinations (such as fall Acadian Flycatcher) that failed to meet analysis criteria described in Methods.

Code	Common name	Scientific name	Spring	Fall
EAWP	Eastern Wood-Pewee	*Contopus virens*	31 May (13 May–14 Jun)	10 Sep (16 Aug–10 Oct)
YBFL	Yellow-bellied Flycatcher	*Empidonax flaviventris*	02 Jun (22 May–15 Jun)	06 Sep (17 Aug–27 Sep)
ACFL	Acadian Flycatcher	*Empidonax virescens*	31 May (13 May–15 Jun)	—
TRFL	Willow/Alder Flycatcher	*Empidonax traillii & E. alnorum*	02 Jun (19 May–15 Jun)	02 Sep (16 Aug–30 Sep)
LEFL	Least Flycatcher	*Empidonax minimus*	21 May (05 May–11 Jun)	04 Sep (17 Aug–05 Oct)
EAPH	Eastern Phoebe	*Sayornis phoebe*	25 Apr (15 Apr–05 Jun)	21 Sep (16 Aug–25 Oct)
GCFL	Great Crested Flycatcher	*Myiarchus crinitus*	06 Jun (12 May–15 Jun)	—
EAKI	Eastern Kingbird	*Tyrannus tyrannus*	25 May (10 May–15 Jun)	25 Aug (15 Aug–20 Sep)
WEVI	White-eyed Vireo	*Vireo griseus*	21 May (29 Apr–15 Jun)	15 Sep (15 Aug–25 Oct)
SOVI	Blue-headed Vireo	*Vireo solitarius*	10 May (26 Apr–31 May)	05 Oct (10 Sep–29 Oct)
WAVI	Warbling Vireo	*Vireo gilvus*	—	11 Sep (17 Aug–07 Oct)
PHVI	Philadelphia Vireo	*Vireo philadelphicus*	—	16 Sep (23 Aug–21 Oct)
REVI	Red-eyed Vireo	*Vireo olivaceus*	30 May (14 May–13 Jun)	20 Sep (22 Aug–25 Oct)
BLJA	Blue Jay	*Cyanocitta cristata*	15 May (20 Apr–11 Jun)	30 Sep (16 Aug–09 Nov)
BCCH	Black-capped Chickadee	*Poecile atricapillus*	08 May (16 Apr–08 Jun)	14 Oct (23 Aug–11 Nov)
ETTI	Tufted Titmouse	*Baeolophus bicolour*	28 Apr (15 Apr–09 Jun)	12 Oct (31 Aug–10 Nov)
RBNU	Red-breasted Nuthatch	*Sitta canadensis*	—	23 Sep (18 Aug–02 Nov)
WBNU	White-breasted Nuthatch	*Sitta carolinensis*	—	07 Oct (17 Aug–14 Nov)
BRCR	Brown Creeper	*Certhia americana*	25 Apr (15 Apr–07 Jun)	09 Oct (11 Sep–04 Nov)
CARW	Carolina Wren	*Thryothorus ludovicianus*	16 May (15 Apr–14 Jun)	06 Sep (15 Aug–05 Nov)
HOWR	House Wren	*Troglodytes aedon*	15 May (26 Apr–13 Jun)	12 Sep (17 Aug–22 Oct)
WIWR	Winter Wren	*Troglodytes troglodytes*	—	11 Oct (18 Sep–10 Nov)
GCKI	Golden-crowned Kinglet	*Regulus satrapa*	22 Apr (15 Apr–06 May)	15 Oct (23 Sep–12 Nov)
RCKI	Ruby-crowned Kinglet	*Regulus calendula*	29 Apr (17 Apr–17 May)	13 Oct (18 Sep–11 Nov)
BGGN	Blue-gray Gnatcatcher	*Polioptila caerulea*	01 May (17 Apr–19 May)	09 Sep (16 Aug–03 Nov)
VEER	Veery	*Catharus fuscescens*	20 May (05 May–08 Jun)	11 Sep (20 Aug–10 Oct)
GCTH	Gray-cheeked/Bicknell's Thrush	*Catharus minimus & C. bicknelli*	27 May (14 May–12 Jun)	01 Oct (13 Sep–03 Nov)
SWTH	Swainson's Thrush	*Catharus ustulatus*	26 May (12 May–10 Jun)	24 Sep (30 Aug–22 Oct)
HETH	Hermit Thrush	*Catharus guttatus*	29 Apr (16 Apr–19 May)	20 Oct (26 Sep–14 Nov)
WOTH	Wood Thrush	*Hylocichla mustelina*	16 May (04 May–06 Jun)	18 Sep (18 Aug–26 Oct)
AMRO	American Robin	*Turdus migratorius*	02 May (15 Apr–13 Jun)	26 Sep (16 Aug–12 Nov)
GRCA	Gray Catbird	*Dumetella carolinensis*	19 May (03 May–12 Jun)	09 Sep (15 Aug–18 Oct)
NOMO	Northern Mockingbird	*Mimus polyglottos*	08 May (17 Apr–07 Jun)	13 Sep (16 Aug–12 Nov)
BRTH	Brown Thrasher	*Toxostoma rufum*	10 May (20 Apr–05 Jun)	25 Sep (15 Aug–31 Oct)
CEDW	Cedar Waxwing	*Bombycilla cedrorum*	26 May (21 Apr–15 Jun)	02 Oct (17 Aug–10 Nov)
BWWA	Blue-winged Warbler	*Vermivora pinus*	—	03 Sep (16 Aug–24 Oct)
TEWA	Tennessee Warbler	*Vermivora peregrina*	23 May (13 May–03 Jun)	20 Sep (19 Aug–28 Oct)
OCWA	Orange-crowned Warbler	*Vermivora celata*	—	15 Oct (25 Sep–14 Nov)

APPENDIX. Continued.

Code	Common name	Scientific name	Spring	Fall
NAWA	Nashville Warbler	*Vermivora ruficapilla*	16 May (30 Apr–10 Jun)	23 Sep (17 Aug–31 Oct)
NOPA	Northern Parula	*Parula americana*	19 May (02 May–09 Jun)	29 Sep (25 Aug–30 Oct)
YWAR	Yellow Warbler	*Dendroica petechia*	21 May (05 May–10 Jun)	29 Aug (15 Aug–02 Oct)
CSWA	Chestnut-sided Warbler	*Dendroica pensylvanica*	22 May (03 May–12 Jun)	06 Sep (17 Aug–22 Oct)
MAWA	Magnolia Warbler	*Dendroica magnolia*	24 May (10 May–10 Jun)	18 Sep (25 Aug–22 Oct)
CMWA	Cape May Warbler	*Dendroica tigrina*	—	05 Sep (16 Aug–13 Oct)
BTBW	Black-throated Blue Warbler	*Dendroica caerulescens*	18 May (05 May–04 Jun)	25 Sep (23 Aug–25 Oct)
MYWA	Yellow-rumped (Myrtle) Warbler	*Dendroica c. coronata*	06 May (16 Apr–26 May)	18 Oct (24 Sep–15 Nov)
BTNW	Black-throated Green Warbler	*Dendroica virens*	22 May (03 May–13 Jun)	22 Sep (21 Aug–31 Oct)
BLBW	Blackburnian Warbler	*Dendroica fusca*	26 May (13 May–10 Jun)	09 Sep (21 Aug–19 Oct)
PRAW	Prairie Warbler	*Dendroica discolor*	13 May (26 Apr–04 Jun)	06 Sep (16 Aug–21 Oct)
WPWA	Palm Warbler (western)	*Dendroica p. palmarum*	—	06 Oct (08 Sep–12 Nov)
YPWA	Palm Warbler (yellow)	*Dendroica p. hypochrysea*	28 Apr (16 Apr–14 May)	—
BBWA	Bay-breasted Warbler	*Dendroica castanea*	23 May (13 May–07 Jun)	04 Sep (17 Aug–10 Oct)
BLPW	Blackpoll Warbler	*Dendroica striata*	28 May (12 May–15 Jun)	26 Sep (03 Sep–29 Oct)
BAWW	Black-and-White Warbler	*Mniotilta varia*	15 May (30 Apr–05 Jun)	07 Sep (15 Aug–18 Oct)
AMRE	American Redstart	*Setophaga ruticilla*	28 May (12 May–13 Jun)	09 Sep (16 Aug–13 Oct)
OVEN	Ovenbird	*Seiurus aurocapilla*	19 May (03 May–05 Jun)	08 Sep (16 Aug–24 Oct)
NOWA	Northern Waterthrush	*Seiurus noveboracensis*	19 May (03 May–05 Jun)	07 Sep (16 Aug–17 Oct)
CONW	Connecticut Warbler	*Oporornis agilis*	—	19 Sep (31 Aug–16 Oct)
MOWA	Mourning Warbler	*Oporornis philadelphia*	03 Jun (21 May–15 Jun)	09 Sep (15 Aug–17 Oct)
COYE	Common Yellowthroat	*Geothlypis trichas*	22 May (06 May–10 Jun)	11 Sep (16 Aug–27 Oct)
WIWA	Wilson's Warbler	*Wilsonia pusilla*	23 May (11 May–08 Jun)	11 Sep (21 Aug–20 Oct)
CAWA	Canada Warbler	*Wilsonia canadensis*	28 May (13 May–11 Jun)	01 Sep (16 Aug–28 Sep)
YBCH	Yellow-breasted Chat	*Icteria virens*	—	19 Sep (21 Aug–06 Nov)
SCTA	Scarlet Tanager	*Piranga olivacea*	—	13 Sep (16 Aug–21 Oct)
RSTO	Eastern Towhee	*Pipilo erythrophthalmus*	08 May (20 Apr–05 Jun)	27 Sep (16 Aug–05 Nov)
ATSP	American Tree Sparrow	*Spizella arborea*	—	05 Nov (16 Oct–16 Nov)
CHSP	Chipping Sparrow	*Spizella passerina*	09 May (21 Apr–03 Jun)	—
FISP	Field Sparrow	*Spizella pusilla*	07 May (19 Apr–12 Jun)	21 Oct (02 Sep–14 Nov)
SAVS	Savannah Sparrow	*Passerculus sandwichensis*	07 May (16 Apr–31 May)	—
FOSP	Fox Sparrow	*Passerella iliaca*	—	29 Oct (08 Oct–14 Nov)
SOSP	Song Sparrow	*Melospiza melodia*	25 Apr (15 Apr–09 Jun)	29 Sep (16 Aug–09 Nov)
LISP	Lincoln's Sparrow	*Melospiza lincolnii*	22 May (05 May–09 Jun)	01 Oct (03 Sep–29 Oct)
SWSP	Swamp Sparrow	*Melospiza georgiana*	11 May (17 Apr–04 Jun)	12 Oct (16 Sep–09 Nov)
WTSP	White-throated Sparrow	*Zonotrichia albicollis*	04 May (18 Apr–22 May)	10 Oct (13 Sep–12 Nov)
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*	14 May (30 Apr–26 May)	12 Oct (20 Sep–31 Oct)
SCJU	Dark-eyed (Slate-colored) Junco	*Junco h. hyemalis*	21 Apr (15 Apr–17 May)	18 Oct (14 Sep–14 Nov)

APPENDIX. Continued.

Code	Common name	Scientific name	Spring	Fall
NOCA	Northern Cardinal	*Cardinalis cardinalis*	04 May (15 Apr–12 Jun)	03 Oct (16 Aug–12 Nov)
RBGR	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	18 May (26 Apr–05 Jun)	12 Sep (18 Aug–24 Oct)
INBU	Indigo Bunting	*Passerina cyanea*	25 May (25 Apr–14 Jun)	30 Sep (19 Aug–31 Oct)
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	11 May (18 Apr–12 Jun)	—
COGR	Common Grackle	*Quiscalus quiscula*	09 May (18 Apr–13 Jun)	—
BHCO	Brown-headed Cowbird	*Molothrus ater*	03 May (15 Apr–13 Jun)	—
OROR	Orchard Oriole	*Icterus spurius*	18 May (10 May–03 Jun)	—
BAOR	Baltimore Oriole	*Icterus galbula*	20 May (09 May–14 Jun)	28 Aug (15 Aug–09 Oct)
PUFI	Purple Finch	*Carpodacus purpureus*	—	03 Oct (21 Aug–05 Nov)
HOFI	House Finch	*Carpodacus mexicanus*	08 May (15 Apr–14 Jun)	12 Sep (16 Aug–16 Nov)
AMGO	American Goldfinch	*Carduelis tristis*	19 May (18 Apr–15 Jun)	25 Oct (20 Aug–15 Nov)